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Volume 14 March, 1928 Number 3

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

The Factors Involved in Lubricating the Steam Turbine

PUBLISHED MONTHLY BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

TEXACO LUBRICANTS

For Steam Turbines

MAKE	Type M = Marine NC = Non-condensing	Drive D = Direct G = Geared	Mode of Lubrication Bearings R O = Ring Oiled F F = Force Feed G L = Grease Lubricated	Mode of Lubrication Gears F F = Force Feed	TEXACO LUBRICANTS RECOMMENDED
Allis-Chalmers Mfg. Co.	Parsons	D	F F		**Regal Oil "A"**
	Parsons (N C)	D	F F		**Regal Oil "C"**
	Parsons	G	F F	F F	**Regal Oil "C"**
Bath Iron Wks., Ltd.	Parsons (M)	D	F F		**Marine Turbine Oil M**
		G	F F	F F	**Marine Turbine Oil H**
Bethlehem Shipbldg. Corp	Curtis (M)	G	F F	F F	**Marine Turbine Oil H**
Carling Turbine Blower Co.	Carling	D	G L		**Star Greases**
Coppus Engineering Corp.	Curtis	D	R O		**Regal Oil "C"**
		D	G L		**Star Greases**
De Laval Steam Turbine Co.	De Laval	D	R O		**Regal Oil "B"**
		D	F F		**Regal Oil "A"**
	De Laval	G	F F	F F	**Regal Oil "C"**
	De Laval (M)	G	F F	F F	**Marine Turbine Oil H**
Elliott Company	Economy and Rateau	D	F F		**Regal Oil "B"**
		D	R O		**Vanguard Min. Cyl. Oil** *(non-water cooled bearings)*
		D	R O		**Regal Oil "C"** *(water-cooled bearings)*
		G	F F	F F	**Regal Oil "C"**
W. & A. Fletcher Company	Parsons (M)	G	F F	F F	**Marine Turbine Oil H**
General Electric Company	Curtis	D	F F		**Regal Oil "A" or "B"**
		G	F F	F F	**Regal Oil "C"**
	Curtis (M)	D	F F		**Marine Turbine Oil M**
	Curtis (M)	G	F F	F F	**Marine Turbine Oil H**

(Continued on Inside Back Cover)

Note: (a) On direct drive turbines, where bearings are lubricated by force feed, if temperature conditions are abnormal, substitute Regal Oil "B" for Regal Oil "A."

(b) On geared turbines, if temperature conditions are abnormal, substitute Regal Oil "E" for Regal Oil "C."

(c) On ring oiled bearings, where temperature conditions are abnormal, it may be necessary to substitute Vanguard Mineral Cylinder Oil for Regal Oils.

(d) For the lubrication of turbines not listed above, if conditions are such that the proper grade of Texaco Lubricants cannot be determined upon by comparison, a communication to the Technical Division of The Texas Company will bring an accurate recommendation promptly.

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The Factors Involved in Lubricating the Steam Turbine

OPERATION of the modern steam turbine requires the most careful attention to bearing lubrication, if power production is to be developed and maintained in the most efficient manner. In fact it may be fairly stated that ultimate continuity of service will virtually depend on how effectively the bearings are protected.

Where steam driven units are involved, they will usually be horizontal. The hydro-electric machine, however, is more generally designed for vertical operation, its bearings being known as thrust and steady bearings.

How effectively they will operate will depend upon four essential factors, viz.:

The nature and purity of the lubricating oil,
The means employed for oil re-conditioning,
The means provided for preventing contamination, and
The provisions for oil cooling.

TURBINE OILS

The outstanding requirement imposed upon a turbine oil is that it shall be of the highest degree of refinement, to insure as nearly absolute purity as possible.

The turbine is probably the most exacting machine to lubricate in the field of power plant or industrial engineering. By virtue of its construction, its actual existence as an operating piece of machinery may be said to depend upon the extent to which its bearings are protected by lubrication.

In turn, the extent to which a turbine oil can be relied upon will depend upon:

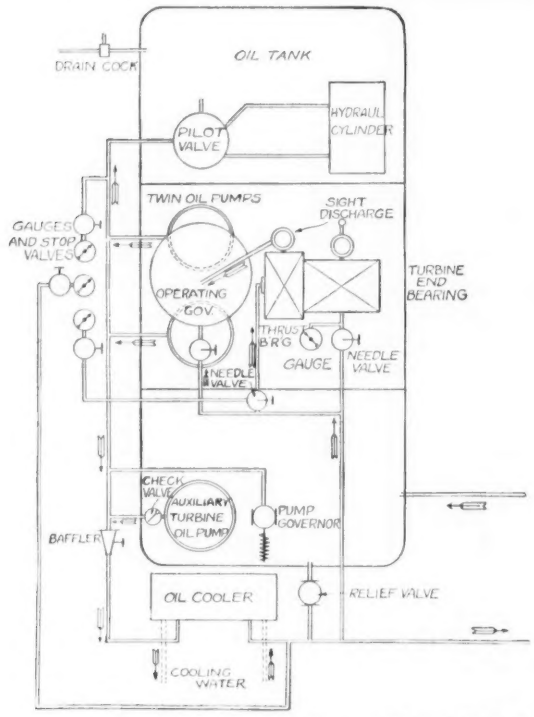
Its resistance to emulsification,
The manner of refinement,
The viscosity,
The extent to which oxidation may occur,
Its resistance to sludge formation, and
The means provided to prevent entry of water.

Emulsibility

Emulsibility is indicative of the extent to which an oil will emulsify with water. This is of vital importance where turbine oils are concerned, in view of the fact that wherever an emulsion may prevail to any extent impaired lubrication may result. In fact emulsification is in general the forerunner of sludge formation, which latter, in its turn, may ultimately lead to oil ways or other parts of the lubricating system becoming clogged.

Emulsibility is determined in the laboratory by simulating the extent to which agitation of a lubricant may occur in actual operation, and then noting the readiness with which separation of the resultant oil-water emulsion will occur. The object, of course, is to study the emulsifying tendency of the oil. There is, therefore, a distinct relation between *emulsification*, or the rate at which an emulsion will develop when an oil is agitated with water, and *demulsibility*, or the rate at which this emulsion will subsequently precipitate itself or settle out.

Wherever water may gain entry into a turbine lubricating system, the possibility of emulsification and the subsequent demulsibility must be given the most careful attention,



Courtesy of General Electric Co.

Fig. 1—Diagram of lubricating system for Curtis steam turbines of 30,000 Kw. and above.

not only when making initial selection and purchase of a lubricating oil, but also in its subsequent usage.

Degree of Refinement Important

Demulsibility, or the rate at which an oil will clarify itself of emulsified matter, and the completeness of this reaction will depend to a certain extent upon the base or nature of the crude from which it has been originally refined.

More particularly, however, will demulsibility depend upon the degree of refinement employed. For the more specific information of the layman this means the extent to which the oil is a straight-run product or pure distillate, the care used in fractionating or segregation of distillates of a narrow range of viscosity, and the extent to which these distillates designed for turbine service are subsequently filtered.

The use of blends, or in other words the addition of a heavier residual or distillate product for the purpose of increasing the viscosity or body of an oil, will very frequently affect the extent of separation of the subsequent product to a marked degree, especially if filtering has not been complete.

It is well to remember that with heavier or more viscous oils emulsified matter will settle out more slowly than from more fluid products or those of lighter body. This will be especially true where the same conditions of refinement hold true.

This is one reason why a turbine oil should be of comparatively low viscosity, commensurate, of course, with other conditions, such as the operating temperature of the bearings, the gallonage capacity of the lubricating system, the period of rest, and the means provided for separation of non-lubricating foreign matter.

Method of Test

The method of determining the relative emulsifying tendencies of lubricating oils as outlined in Bureau of Mines Technical Paper 323-A follows:

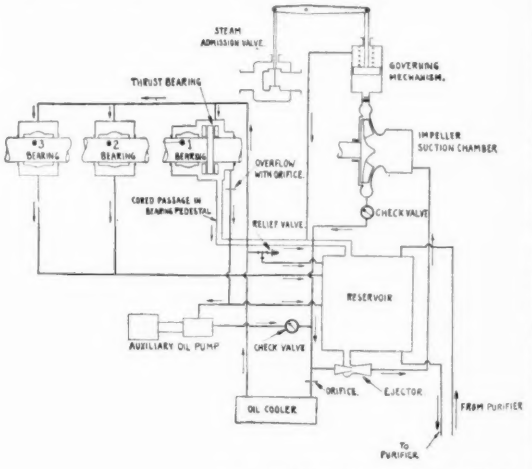
Apparatus

1. A 100 c.c. graduated cylinder, $1\frac{1}{16}$ to $1\frac{1}{8}$ inches inside diameter.

2. An oil or water bath for maintaining the contents of the cylinder at the specified temperature. The line of the bath liquid shall not be lower than the 85 c.c. mark on the graduated cylinder.

3. A paddle consisting of a copper plate $4\frac{3}{4}$ inches long, between $\frac{3}{4}$ and $\frac{7}{8}$ inch wide, and $\frac{1}{16}$ inch thick.

4. Means for revolving this paddle about a vertical axis parallel to and midway between its longer edges and for keeping the speed fairly constant at 1,500 r.p.m.



Courtesy of Westinghouse Elect. & Mfg. Co.

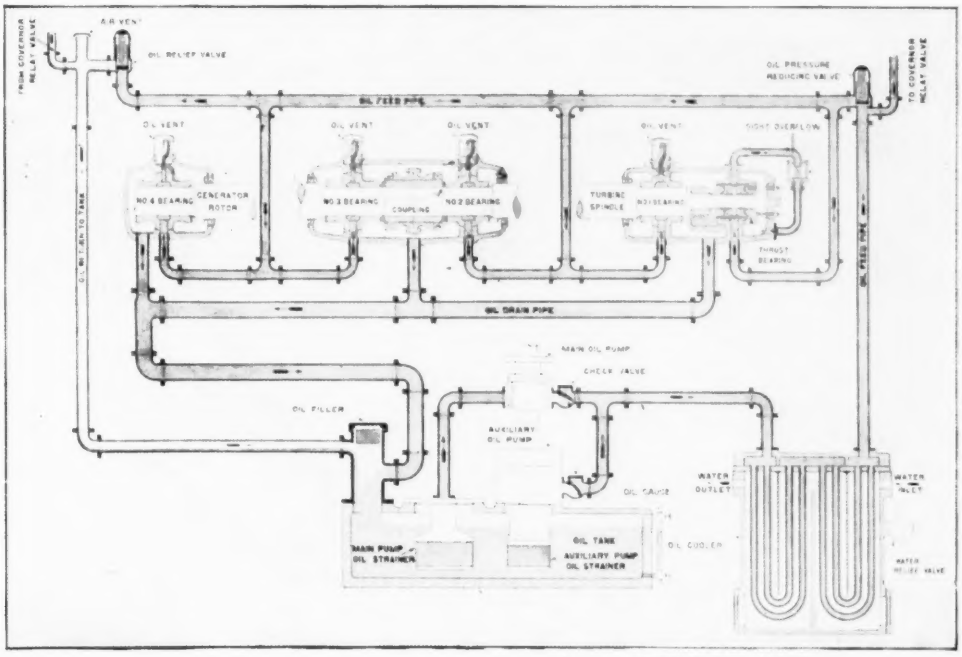
Fig. 2—Flow of oil to and from bearings and through other parts of a turbine lubricating system is clearly shown here.

5. A stop so arranged that when the paddle is lowered into the cylinder the distance from the bottom of the paddle to the bottom of the cylinder will be about one-fourth inch.

Procedure

6. Place 40 c.c. of the emulsifying liquid in the 100 c.c. graduated cylinder and add 40 c.c. of the oil to be tested.

9. Allow the cylinder to stand at 130 degrees F. for the specified time and then inspect. No continuous layer of emulsion shall remain.



Courtesy of Allis-Chalmers Mfg. Co.

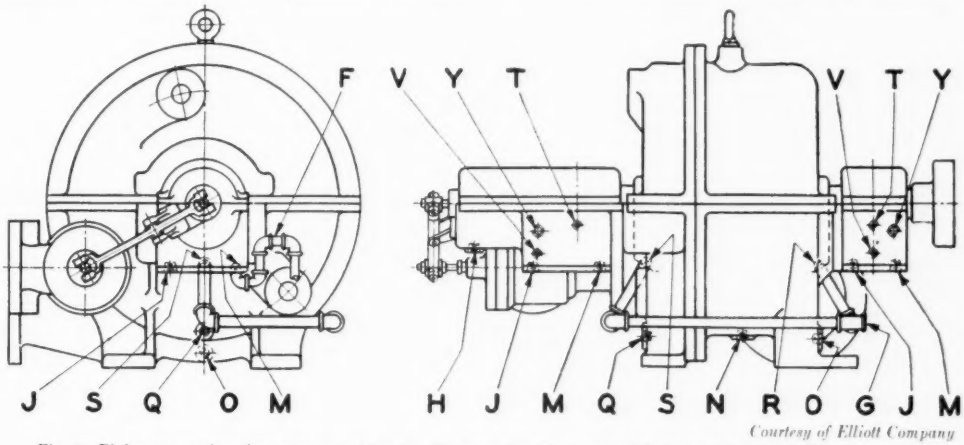
Fig. 3—Another method of showing the scheme of lubrication for a modern steam turbine. Here again flow of oil can be traced by arrows.

7. Heat the cylinder by means of the bath to 130 degrees F. for oils of 330 seconds Saybolt viscosity, or below. For oils of higher viscosity heat to 180 degrees F.

8. Stir by rotating the paddle for five minutes at a speed of 1,500 r.p.m., stop the paddle, withdraw from the cylinder and wipe clean, returning to the cylinder as much of the emulsion as possible.

THE VISCOSITY FACTOR

In order for an oil to lubricate it must be of the proper viscosity, for solid friction must be absolutely supplanted by fluid friction, this latter in turn being as low as possible.

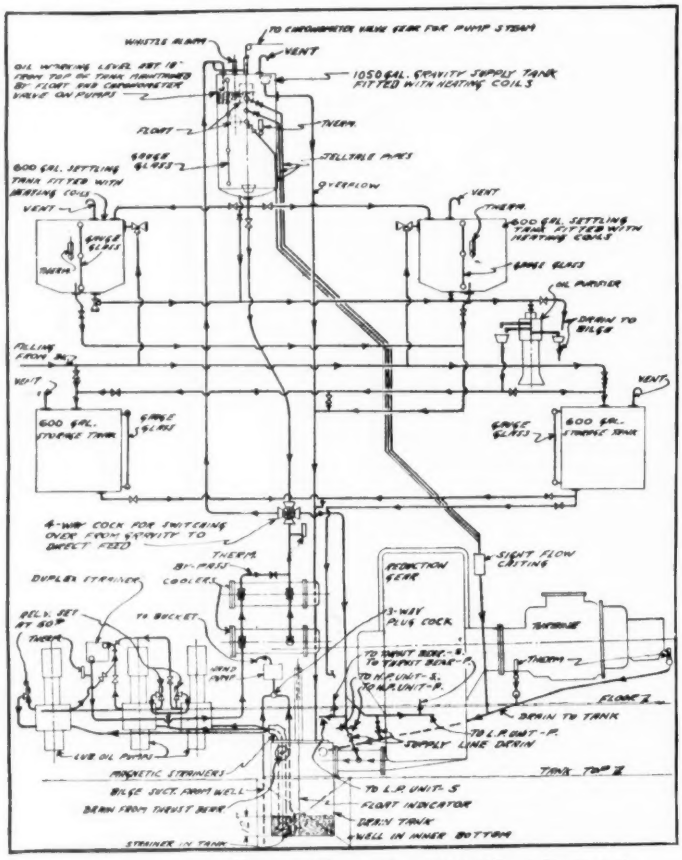


Courtesy of Elliott Company

Fig. 4—Piping connections for a steam turbine, i.e., F—water leg, G—open end drain (packing cases), H—clean-out drain, J—water inlet, M—water outlet, N—inter-stage drain, O—exhaust end drain, Q—steam end drain, R & S—packing case leakage pipes, T—oil supply line (forced feed), V—oil indicator and clean-out, and Y—oil drain line (forced feed).

The viscosity or body of the oil is the controlling element, contingent, of course, upon the clearance spaces which exist between the shafts and bearings. As a general rule, the higher the

clearances and the more accurately these are expanded by chamfering of the bearing edges at the point of entry of the oil, the more easily will the shaft be able to draw a suitable film of oil into this space. On the other hand, if the viscosity is too low the oil may not be able to withstand the bearing pressures involved, or if it is too high there may be altogether too much internal friction brought about. Either of these conditions will lead to an appreciable increase in operating temperatures.



Courtesy of Newport News Shipbuilding & Dry Dock Co.

Fig. 5—Elevation view of the lubricating oil system for a marine steam turbine. Essential piping and accessories can be readily traced, as can also flow of oil.

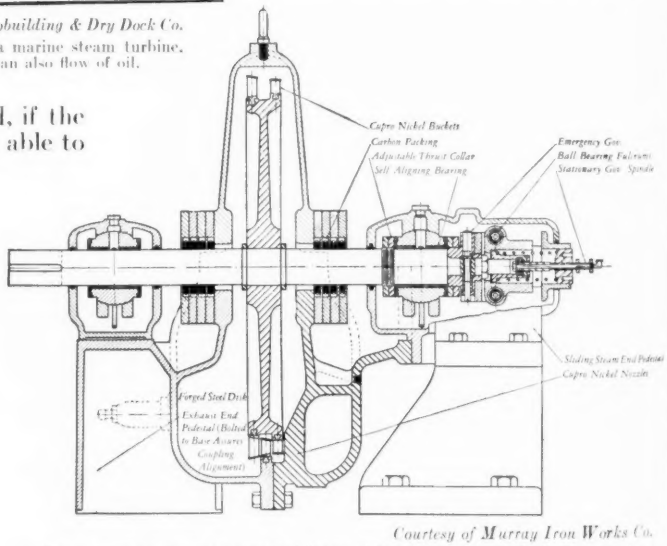
As a rule, the operator should have little difficulty in selecting an oil of the proper viscosity to meet his operating conditions, inasmuch as turbine builders and oil refiners, in company with the technical experts of a number of public utilities, have cooperated to a sufficient extent to prove that an oil for pressure lubrication of turbine bearings should normally vary from 140-200 seconds Saybolt at 100 degrees F. Ring oiled bearings, however, may require a somewhat heavier oil, according to the prevailing temperatures.

Where reduction gears are involved, whenever the same oil is to be used for lubrication of both gears and bearings, a certain increase in viscosity will be necessary in order to insure effective lubrication of the gears. Here duty will be considerably heavier, imposing pressures on the lubricating film in excess of those involved in the bearings.

On the other hand, this lubricant must not be so heavy as to lead to the development of abnormal internal friction within itself when in service in the bearings. An oil with a steep viscosity curve has been found to be the most adaptable for such service; that is, it should adhere to its original viscosity as nearly as possible when in service in the gear case; yet be capable of decreasing so rapidly in viscosity with normal increases in temperature that when fed to the bearings at temperatures in the neighborhood of 140 degrees F., it will be reduced to approximately the viscosity of the lighter oil which would normally be used for bearing lubrication alone.

Oil for Reduction Geared Units

Wherever an oil is to be used for the lubrication of both reduction gears and bearings it should seldom have a viscosity below 300 seconds Saybolt at 100 degrees F. In general, an oil of this viscosity will function with perfect satisfaction in the average stationary, reduction geared turbine.



Courtesy of Murray Iron Works Co.

Fig. 6—Section through a standard Frame D Turbine showing self-aligning bearings and other essential parts.

In the marine service, on the other hand, the size of the gears may be considerably larger, with corresponding increases in tooth pressures. Under such conditions, it will often be found advisable to use an oil of approximately 500 seconds Saybolt viscosity at 100 degrees F., or even higher under abnormal service.

An important point to remember, however, in the lubrication of reduction geared turbines, is that an oil should never be of any higher viscosity than absolutely necessary, due to the fact that the heavier the oil the less readily will it separate from water.

Internal Friction must be Considered

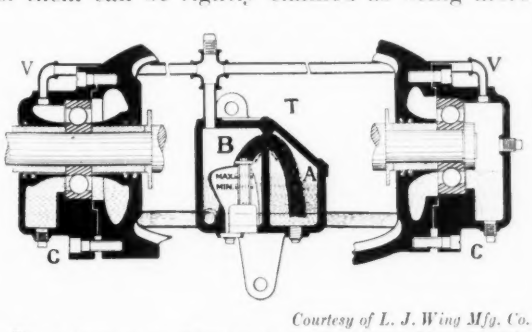
Furthermore, unless bearing temperatures are above the average, there will be a tendency for marked increase in internal friction due to the oil being too heavy for the service involved. This, of course, would lead to a certain increase in temperature, which would automatically tend to reduce the viscosity to a certain extent, with the result that ultimately an equilibrium temperature would be reached. Also this increase in temperature will tend to increase the sludge formation.

Actually, therefore, the operator must watch his turbine temperatures carefully. If they tend to run above 140 degrees F., unless there are certain mechanical conditions involved to which this can be directly attributed, he would be safe in investigating the suitability of his oil or the extent to which foreign matter and sludge are being removed.

OXIDATION

Mineral oils will be subjected to more or less oxidation when agitated with water under higher temperatures in the presence of air.

These conditions are normally so involved and so contingent upon one another that no one of them can be rightly claimed as being more

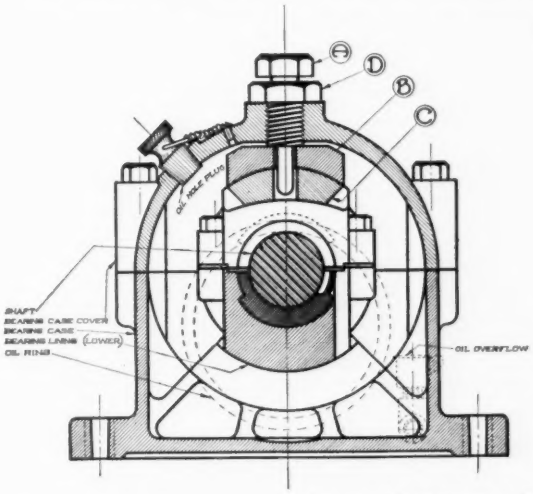


Courtesy of L. J. Wing Mfg. Co.

Fig. 7—Cross section of bearing of a turbine blower. Note the wick-lubricated ball bearings. "A" and "B" are two separate oil compartments connected solely by means of a set of wicks which replenish any oil that is used up out of "B". At "V" are shown the oil vents.

detrimental than the other. On the whole, however, it may be stated that the extent to which oxidation will occur depends largely upon the refinement of the original oil. In other words, certain petroleum hydrocarbon fractions will probably oxidize more readily than others.

Logically, therefore, it would be advisable



Courtesy of B. F. Sturtevant Co.

Fig. 8—Line sketch of a turbine ring-oiled bearing. "A" is an adjusting bolt which, by tightening down, causes the spherical seat "B" to grip the linings "C"; "D" is a lock nut to hold "A" in position. With this arrangement shims between the bearing cases can be eliminated.

to bend every effort in the refinery to effect the removal of these components by more accurate refining. The more reliable the manufacturer, naturally the more dependence can be placed on his methods of refining.

Oxidation will of course occur in practically any oil if it is subjected to oxidizing conditions. In fact, wherever particles of air and water are suspended or retained within the body of an oil to form an emulsion, only a slight elevation of temperature during circulation or agitation will be necessary to bring about an oxidizing reaction between the air and oil.

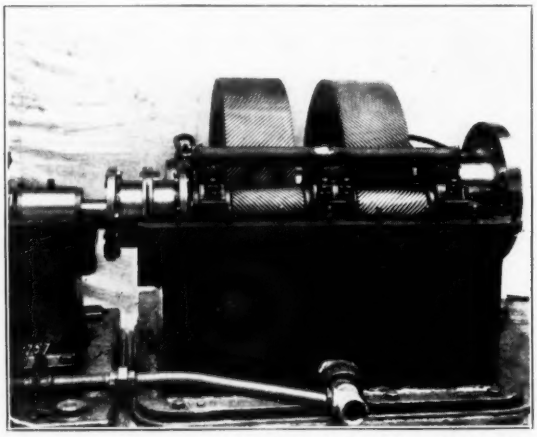
Metallic Particles a Factor

Oxidation furthermore is claimed to be aided by metallic particles, especially brass, copper and iron, or other foreign matter, such as dust and dirt. In fact, in an already emulsified oil foreign matter of this nature is regarded as being the co-partner of oxidation in producing the resultant insoluble sludges so detrimental to proper lubrication.

It is believed by some that if emulsion is prevented, sludging will be greatly lessened. But emulsion involves only air and water. It would, therefore, seem logical to consider foreign matter, or the catalyzers which promote oxidation, as an equal detriment.

Emulsions alone are certainly not as viscous, adhesive and generally objectionable as insoluble sludges which so frequently clog oil passages, congest the oiling system and generally reduce the lubricating quality of the oil.

The natural procedure is therefore to reduce the effect by removing the cause as far as possible. In other words, by purifying the oil during operation to a sufficient degree to keep down the percentage of water, emulsion and foreign matter.



Courtesy of De Laval Steam Turbine Co.

Fig. 9—Gears and pinions of a modern reduction geared steam turbine showing lubricating oil piping.

The latter can also be prevented to a considerable extent by using steel piping and fittings throughout the oiling system, for steel has the least tendency to chip, corrode or otherwise contaminate the oil with metallic particles as it passes through the lubricating system.

SLUDGE FORMATION A DETRIMENT

The subjecting of an over-heated turbine oil to agitation in the presence of air or water will normally cause the formation of permanent sludge. Sludge is generally agreed upon as passing through two stages in its formation, i.e.:

1st. The colloidal or soluble stage, and

2nd. The insoluble stage.

In the colloidal stage if water is present, fairly stable emulsions may be formed. On the other hand, the presence of an emulsion is not necessarily indicative of colloids. Both emulsions and colloidal sludges are relatively temporary at normal operating temperatures.

Emulsions, if uncontaminated and unoxidized, will clarify themselves and precipitate water on standing, leaving the bulk of the oil in very nearly the same condition as prior to agitation.

Colloidal sludges (or, as they may also be termed, soluble sludges), in turn, at temperatures above approximately 100 degrees F. will be held in suspension in oil. Yet while both emulsions and colloidal sludges can be apparently readily dissipated from, or absorbed by, the oil, they are nevertheless a detriment to lubrication while present, due to the fact that the formation of a continuous, uniform oil film over the surface to be lubricated is impaired.

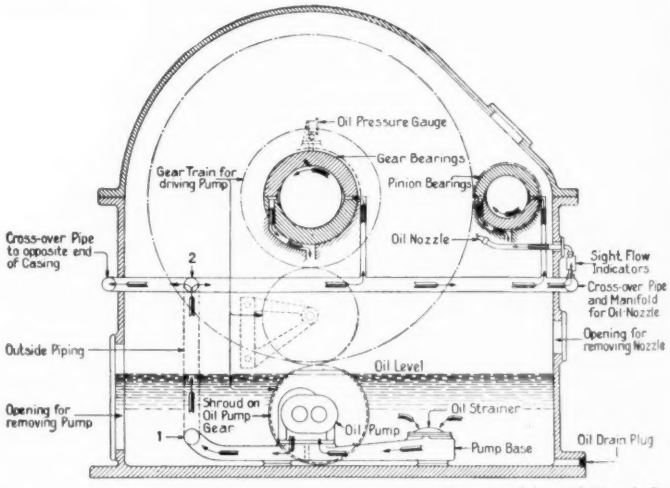
Where breakdown in an oil has occurred, separation of contaminating foreign matter will be interfered with. As a consequence, this latter will be able to exercise its catalyzing effects to cooperate with oxidation in the bringing about of permanent sludges.

Of course, where colloidal sludges have passed over to the state of insolubility, immediate steps should be taken to correct this by the removal of the heavy, adhesive and relatively solid matter from the system, otherwise lubrication will be bound to be impaired.

In contrast Gilson* is of the opinion, however, that oxygen is a necessary factor in maintaining the internal friction within the lubricant as low as possible. He furthermore believes that in all probability, it is the reaction of sludge formation and not this product itself which is of importance.

On the other hand, even though this may be essential to the attainment of satisfactory lubrication, the resultant product, i.e., the sludge is a detriment, just as has been stated heretofore.

Therefore, due to its natural tendency when in an insoluble state, to accumulate in the oil pipes and oil ducts and not only impair the circulation of the oil, but also bring about an increase in internal friction, it is evident that this sludge should be removed. In its formation, it is directly influenced by the temperature of operation. Therefore this latter should



Courtesy of General Electric Co.

Fig. 10—Lubricating system for steam turbine reduction gears, where pinion is subject to clockwise rotation. All parts are plainly indicated. Arrows show direction of oil flow.

*E. G. Gilson, "Some Bearing Investigations," "General Electric Review," May, 1924.

be kept down as much as possible. Where the oiling system is free from congested matter, the oil itself will be able to carry out its partial function of serving as a bearing coolant most effectively.

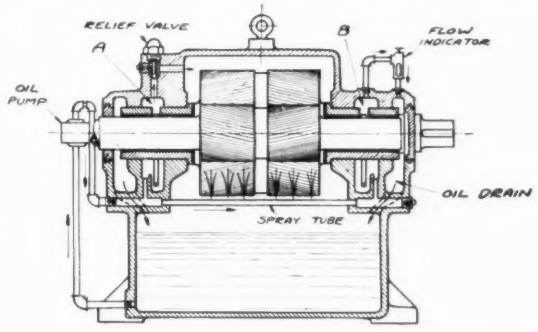
WATER AND ITS EFFECT ON TURBINE OILS

The detrimental effects of water have already been mentioned in discussing oxidation, emulsification and sludge formation. In fact, water is regarded by many authorities as the basic cause of emulsification. Therefore, if a turbine and oiling system could be so designed as to eliminate the chances of water leakage or condensation occurring, provided the original oil was water-free there would very probably be but little emulsion developed.

We must grant, however, that the presence of a certain amount of water and other impurities is a certainty. As a result, emulsions and sludges will be formed in the average turbine. Effective oil purification should bring about the removal of these, before their proportion becomes dangerous. From the turbine builder's viewpoint, therefore, his machine and oiling system should be so designed as to permit of ready separation of impurities from the oil by means of the reconditioning apparatus.

How Water Gains Entry

The entry of water may occur through steam leaks on account of the shaft packing glands or water seals not functioning properly; through

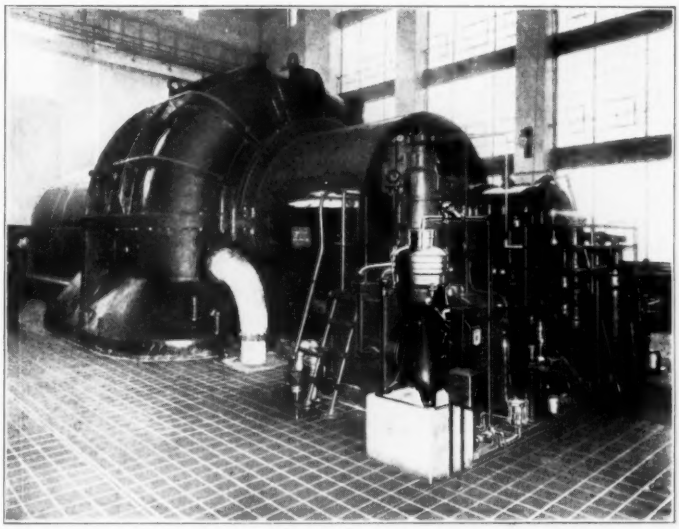


Courtesy of Moore Steam Turbine Corp.

Fig. 11—Diagram of oiling system for turbine reduction gears, with path of circulation clearly indicated. Note that here the oil pump, is located on a level with the bearings, whereas in Fig. 10 it is shown in the oil sump.

leaks in the cooling coils of the oil cooler; or, as is more usually the case, from condensation of moisture in the air. Especially is this latter liable to occur when the turbine is shut down, at which time the inner metallic surfaces of the lubricating system will be relatively cold, serving more readily as a condensation medium.

Water is considered detrimental to a turbine oil in service in that it is an active agent in the formation of emulsion and, under some conditions, sludge. Where the oil is in a sufficient state of purity, separation from water will normally occur comparatively readily, for the emulsion caused by agitation will be of a relatively temporary character. A mixture of water and oil, however, when subjected to the customary rapid rate of circulation, in the presence of air, and the higher temperatures usually prevalent in turbine service, will oftentimes subsequently develop permanent emulsions.



Courtesy of De Laval Separator Co.

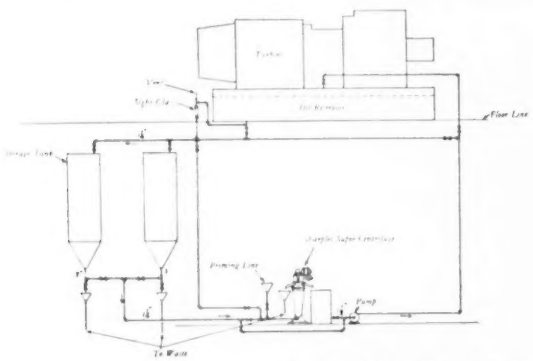
Fig. 12—Showing the practicability of locating a centrifugal purifier, and its relative size in contrast with a large steam turbine.

By some engineers this is believed to be the basic cause of lubricating failures in the average turbine, being the cause of organic acidity and sludge.

Acidic Reactions

The extreme complexity of the acid-forming constituents, such as sulphur, oxygen and nitrogen, and the limited knowledge of their reactional tendencies must also be taken into consideration in regard to this matter of sludging. In other words, were these reactions known more positively, or could turbine oils be so refined as to remove or neutralize their organic acid-forming constituents, certainly the matter of water and the possibility of formation of permanent emulsions and sludges would be of far less importance.

As it is, effort can only be made in refinement to render turbine oils as chemically stable as possible. The most careful attention to the oil throughout the process of refining should always be observed. But no process renders an oil non-reactive when it is subjected to detrimental conditions in the presence of air and water under high temperatures.



Courtesy of Sharples Specialty Co.

Fig. 13—Line sketch of a steam turbine showing piping details and accessories pertinent to the use of a centrifugal oil purifier.

General operating conditions are not conducive to satisfactory lubrication unless the turbine oil is capable of meeting requirements. In the first place, heat and air and water will always be present, since it is practically impossible to build a turbine oiling system so that the parts involved are absolutely airtight. As a result air will get into the oil during its circulation through the system or in splashing over the gears.

Dust and dirt are in turn always present in the air to a certain extent, wherever the oil is in passage. Therefore, it is logical to expect that foreign matter of this nature will find its way into the oil to not only cause abrasion and corrosion, but also to act in the same catalytic manner as metallic particles.

Furthermore, the matter of acid and alkali must be taken into account. A turbine oil should always be neutral from this point of view. As previously discussed, organic acids may or may not be detrimental, depending upon the type of acid.

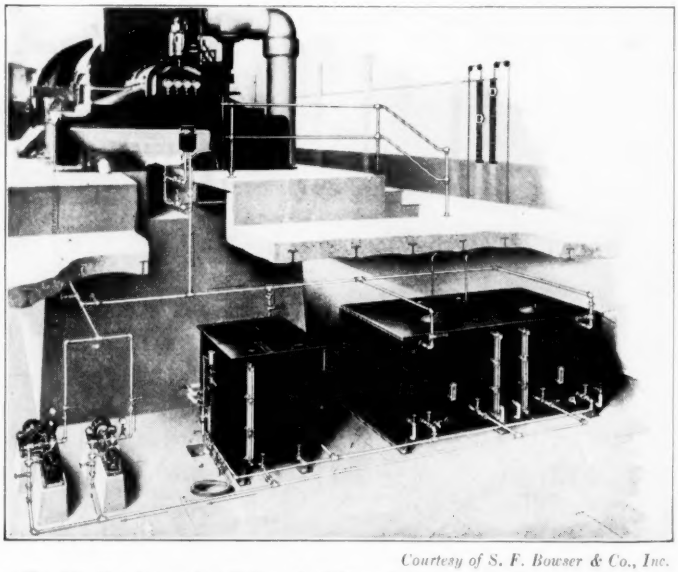
high a state of purity as possible. Only in this way can detrimental conditions of operation be counteracted, such as:

1. The acid-forming effects of heat and air.
2. Emulsification with water.
3. Development of sludges from such emulsifications.
4. The catalyzing effects which dust, dirt and metallic particles (especially of copper and brass), involve in the formation of sludges.

This does not necessarily mean that the oil requires reconditioning until its original characteristics are brought back. In general, operating and installation conditions will not permit of this.

Experiments have proven that, unless the proportions of water, sludge and emulsified matter present are considerable, an oil will normally possess sufficient lubricating and cooling ability to function perfectly satisfactorily; in other words, bearing temperatures will remain below the generally accepted safe limit of 160 degrees F. Yet the oil in circulation at the time might contain a certain amount of the aforesaid recognized impurities, as well as considerable organic acidity.

Essentially, oil purification, filtration or reconditioning have one and the same meaning



Courtesy of S. F. Bowser & Co., Inc.

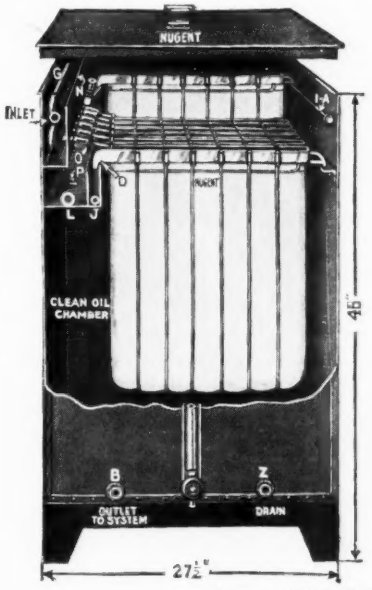
Fig. 14—Showing an installation of oil filters in connection with a steam turbine. Note facility of locating below the operating floor, the simplicity of the piping layout and flow of oil as indicated by arrows.

MAINTENANCE OF CONTINUED SERVICE

Continued service is the salient factor in the operation of a steam turbine. It can be insured, of course, by the maintenance of the oil in as and involve the removal of foreign matter which in any way may tend to impair the lubricating or cooling ability of the oil.

Reconditioning is, perhaps, the most generally understood term and will therefore be used

hereafter where reference is necessary. In its attainment, it is based on one of three distinct principles, that is, the action of centrifugal force, the separation of the impurities from the oil by virtue of difference in specific gravity, or



Courtesy of Wm. W. Nugent & Co.

Fig. 15—Cut-away view of an oil filter showing point of oil inlet, and the filter bags in position. "1 A"—is a rod for suspending raised bags for draining prior to cleaning. G—is a steam or hot water heating coil. L—the general overflow and B—the filtered oil outlet.

the removal of these impurities by means of some filtering medium.

Centrifugal Treatment

Each has its respective place, inasmuch as each is particularly capable of removing certain varieties of foreign matter. For example, where finely divided carbonaceous matter is involved, which would be difficult to remove by precipitation, the addition of a certain amount of water and sometimes coagulants, with the subjection of the mixture to the violent action of centrifugal force has been found to bring about a sufficiently complete state of sludge formation to cause the impurities which are contained in this latter to be readily separated from the oil.

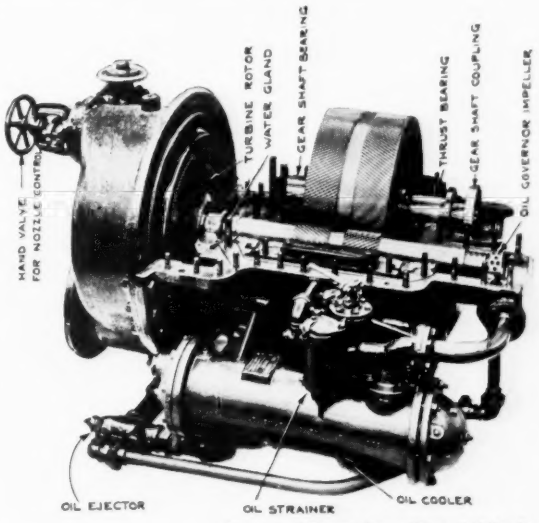
Precipitation and Filtration

Precipitation and filtration are, in general, combined in the construction of the average apparatus which is to remove foreign matter by either one of these methods. In devices of this sort, the oil is first subjected to precipitation, oftentimes the rate at which this latter occurs being increased by heating, or by chemical or mechanical means.

To a great extent, precipitation depends on the length of time the oil is allowed to stand in a perfect state of quietude. It is natural to expect that were precipitation to be attempted in the presence of agitation or any movement of the medium, the efforts of the suspended impurities to settle out would be interfered with. In many cases, however, it will not be possible to give the time necessary for this; therefore precipitation becomes only a preliminary separation of such larger particles of foreign matter as will settle out from the oil in a relatively short space of time.

As to filtration, it may be stated that it is advantageous in that the time element is of relatively no importance. The efficiency which will be attained from filtration will, of course, depend upon the type of material through which the oil is to be filtered and the rate at which it is passed. As stated above, it is not absolutely essential to remove every trace of impurity from a turbine oil. In fact, the oil in the lubricating system always contains a certain amount of foreign matter, with the exception of perhaps the first few minutes after new oil has been put into service.

In consequence, it is safe to say that the extent to which an oil must be cleansed or purified should be the governing factor as to the time of precipitation and the density of the filtering medium, or if both methods are used in combination, the relative effectiveness of each as compared with the volume of oil to be treated and the time available.



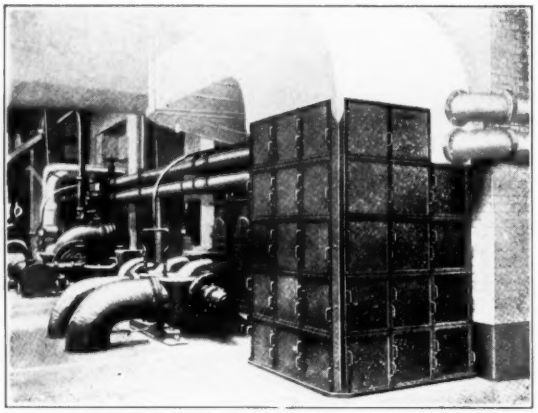
Courtesy of Westinghouse Elect. & Mfg. Co.

Fig. 16—Details of an oil governor adapted to steam turbine service. Essential parts are clearly indicated.

Addition of Water

Water can often be effectively added to a turbine oil which is to be purified by means of centrifugal purification. It should not be assumed, however, that this also applies to the

use of an oil filter. In other words, wet filtration, as it used to be known, or the idea of passing dirty oil through water is obsolete. The impurities are not removed to any extent and the oil particles will tend to absorb water, which will be difficult to remove later on.



Courtesy of Midwest Air Filters, Inc.

Fig. 17—Showing the position which a bank of air filter cells would occupy in a turbo-generating plant.

Series Operation

A very effective, though perhaps a somewhat expensive, way of bringing about the proper reconditioning of turbine oils in the least possible time is to use a centrifugal purifier in series with an oil filter.

On the other hand, many concerns will not care to assume the additional expense entailed in the installation of both of these devices, hence they use whichever they may have available to the best of its ability.

Advantage of Heating

Heating of the oil should always be considered regardless of the means of reconditioning available. As a general rule, in order to facilitate the separation of impurities by reducing the viscosity of the oil, provision is usually made in the modern oil reclaimer for the application of a certain amount of heat, whatever its type. For example, in connection with the operation of the centrifugal purifier with the average turbine oil, it will be found that heating to the neighborhood of 150 degrees F. will oftentimes aid in the separation of the foreign matter. This, of course, will also depend to a certain extent upon the specific gravity of the medium involved.

On the other hand, it must be borne in mind that the application of an excessive amount of heat will tend to bring about the formation of organic acids and additional oxidation. In other words, while it may facilitate the removal of some varieties of foreign matter to a certain extent, it will also lead to the subsequent formation of others, due to the purified oil coming back into service in an acidic state.

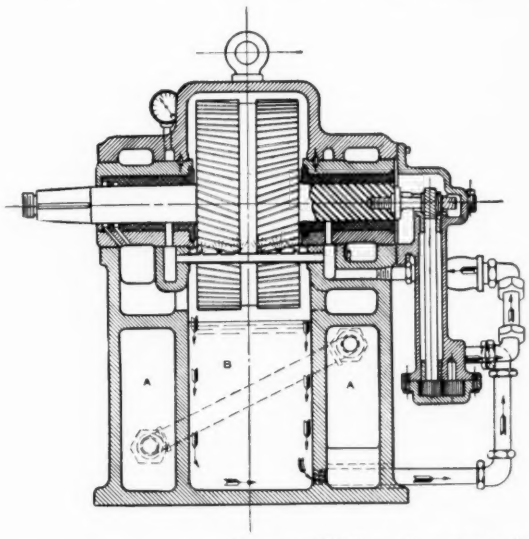
Organic Acidity

Relative to organic acidity, it is interesting to note that of the several impurities which will usually be found in a turbine oil, it is the only one which cannot be satisfactorily removed by any of the standard forms of oil reclaimers.

As yet, however, the extent to which organic acidity is directly detrimental in itself is a point of discussion. In the opinion of authorities, even though there may be no practical means of bringing about its removal from an oil, there is a possibility that addition of water to a turbine oil, prior to centrifugal purification, will, by virtue of the emulsions and sludges formed, tend to automatically reduce the amount of organic acidity.

As a result, the oil which is subsequently put into the system again will be capable of going that much further, before it is once more oxidized, and sufficient organic acidity developed to bring about a dangerous amount of emulsified matter and sludge.

Of course, wherever water is to be added to a turbine oil, this should be done after the charge to be purified has been drawn off or by-passed from this system. Under no condition should this be done while the oil is in circulation, due to the fact that the excess of impurities which would probably be thrown down would form a sufficient amount of additional sludge to congest the system and impair lubrication.



Courtesy of The Terry Steam Turbine Co.

Fig. 18—Sectional view of the Terry reduction gear showing in particular the direction of oil flow, manner of delivery to gear teeth, and the gear-driven oil pump at the right. A—indicates cooling water compartments, B—indicates oil reservoir.

PREVENTION OF OIL CONTAMINATION

In the attainment of effective turbine lubrication the prevention of entry of foreign matter sufficiently fine to be carried by the air is of decided importance.

In other words, to insure effective lubrication of the bearings of turbo-generating equipment, and to prevent injury to electrical windings, it is essential to protect them at all times from entry of abrasive foreign matter.

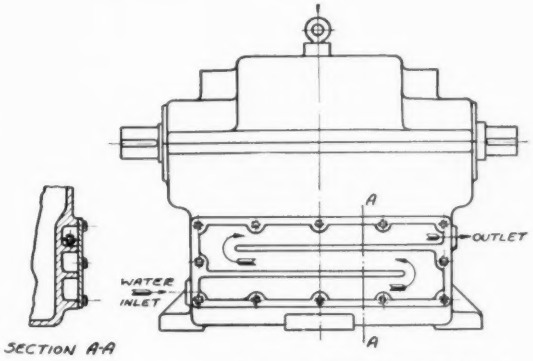
In many such installations there will be possibility of the occurrence of windage, that is, the passage of air through the bearings. This will, of course, depend upon bearing construction and whether provisions are installed for counteraction.

In certain machines baffles or dust guards are employed. These latter will effectively reduce windage, and serve to prevent oil being carried from certain types of bearings. But where there is any draft, and the dust content of the air is comparatively high, there will still be considerable probability of abrasive matter penetrating to bearings, or the windings of generators, to ultimately impair operation.

For this reason it will be advisable to give consideration to air conditions, and the potential benefits to be derived from better lubrication by proper filtering of the air.

Dirty Air a Prevalent Detriment

It is of course impossible to absolutely eliminate dirty air conditions; screening of windows and doors will prevent larger particles of dust from entering, but finer dust will get by to be an ever prevalent detriment to lubrication

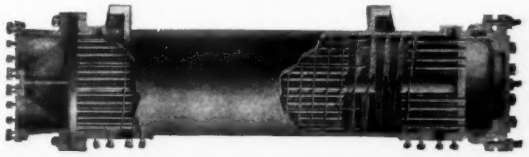


Courtesy of Moore Steam Turbine Corp.

Fig. 19—Showing another method of water cooling the oil adjacent to reduction gears. Note flow of water, as well as sectional detail of the cooling element.

unless steps are taken to remove it from the air which is to actually pass through the equipment or come in contact with the wearing elements to any extent.

Such air should, therefore, be filtered wherever necessary, the volume so treated per hour, let us say, depending upon the size of the filter installation and the requirements of the plant. Normally it will not be necessary to filter all the air which is circulated through any particular room or building. In general, only such air will require filtering as is to come into direct



Courtesy of The Griscom-Russell Co.

Fig. 20—A turbine oil cooler of the multiwhirl type. In this cooler the oil is pumped through the shell, the cooling water passing through the tubes.

contact with the turbo-generating equipment. In this way the lubrication of bearings can be rendered more effective by guarding against the possible contamination of their lubricants with abrasive dust or other foreign matter.

Presence of solid foreign matter in any lubricating film will tend to impair its ability to serve as a friction reducer. This will be largely due to lack of homogeneity in the film and the possible occurrence of actual solid contact between shafting, bearings and such solid foreign matter as may have worked in between them. This explains, in part, why bearing elements frequently become scored or abraided, oftentimes even when lubrication is apparently effective.

Principle of Air Filtration

The modern air filter is based on the principle of the human nostril, in that by suitable arrangement of the filtering media and certain baffles, the passage of dust is arrested even though there is free access for the air. As the filter becomes clogged or its pores or interstices filled with foreign matter, air will pass through with more or less difficulty. It is for this reason that periodic cleaning is necessary.

Usual Filter Construction

The air filter for turbo-generating plant service will, as a rule, involve a suitable container, cell or box in which is contained fine wire such as steel wool, metallic particles, expanded metal sheets, small metallic cylinders or felt vanes, etc.

Where metallic filtering material is used it is regarded as advisable to grade it in coarseness from intake to outlet, the finest media being located adjacent to the clean air outlet. To further aid in the separation of dust from the air, certain authorities deem it advisable to provide for repeated change in the direction of the latter. In one well-known filter involving split wire for filtration, the direction of the air

is claimed to be changed from eleven to eighteen times.

Each change of course tends to throw a certain amount of dust into more intimate contact with the filtering media, to be retained and prevented from further passage through the filter. When metallic filtering material is involved, it will be advantageous and expedient to have it coated with a light film of adhesive fluid in order to promote retention of solid foreign matter. Light lubricating oil having a viscosity of from 200 to 300 seconds Saybolt at 100 degrees F. has proven to be suitable for this purpose.

TEMPERATURE REDUCTION A FACTOR

The extent to which a turbine oil will be subjected to high temperatures will depend upon the turbine itself, the rate at which the oil is being circulated, and the provisions for oil cooling.

During operation, the oil may either receive heat from an external source, such as the steam, or abnormal heat may be developed within the bearing, due to imperfections in the lubricating system, causing unusual internal friction.

Heat as received from steam may be either conducted or radiated. At the high pressure end of the machine conduction will be more probable, for steam at temperatures in the neighborhood of 600 degrees F. will certainly impart considerable of this heat to the adjacent bearings, regardless of the provisions for cooling these latter.

Transmission of heat by radiation to the bearings as well as to the oil piping, will also occur to a certain extent, although this will naturally depend upon the provisions for ventilation and the operating temperature of the turbine room.

Effect of Room Temperature

In connection with this matter of temperature, it is interesting to note that as a general rule room temperature variations which are often regarded as negligible factors, are in reality of considerable importance.

Frictional Heat

The generation of abnormal heat within a bearing may be the result of an excess of internal friction, due to the oil being too heavy or viscous, the circulation being too rapid, or perhaps the oil ways or ducts being partly clogged by emulsified matter.

It is difficult to determine offhand just what the cause for overheating may be unless there is but little opportunity for the bearing to receive heat from external sources. In this event faulty lubrication can in general be assumed as being the cause.

Effective Oil Cooling Essential

Inasmuch as one of the chief functions of a turbine oil is to serve as a bearing coolant, it is perfectly evident that every precaution must be taken to keep the oil under circulation as cool as possible, otherwise its viscosity, and hence its pressure-supporting ability will be reduced, sometimes even to such an extent as to render the film incapable of keeping the shaft from coming into actual metal-to-metal contact with the bearing.

While heat alone will lead but to the possibility of faulty lubrication from the viewpoint of lack of pressure-resisting ability, heat in company with water and air is the forerunner of oxidation, emulsification, and the subsequent formation of insoluble sludges. Therefore, every effort should be made to keep turbine bearing (and consequently oil) temperatures as low as possible. This is the primary reason for installing an oil cooler in connection with the lubricating system.

Oil Coolers

A properly designed oil cooler will extract the greater part of the heat absorbed by the oil from the bearings and return the oil to the bearings at a comparatively low temperature.

Cooling the oil permits it to absorb a greater amount of heat from the bearings, thus lowering the bearing temperature and at the same time decreasing the rate of evaporation. On the other hand, if the temperature is carried too low the increased viscosity of the oil will cause a slightly higher bearing friction and retard the rate of separation of water and other foreign matter.

The efficiency of the oil cooler depends upon the initial temperatures of the oil and water, the amount and rate of oil and water circulated, the mechanical design of the oil cooler and the cleanliness of the surfaces of the coils.

The rate of heat absorption in the cooler depends largely upon the rate of flow of the oil film near to the metal surfaces. This rate of flow is again dependent upon the viscosity of the oil, all of which means that high viscosity oils require a much larger cooling surface than more fluid products for the same temperature reduction.

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